

COMMUNITY PERSPECTIVE OF SUSTAINABLE URBAN DRAINAGE SYSTEM TECHNIQUES: A CASE STUDY OF NHIEU LOC – THI NGHE SUB-BASIN IN HO CHI MINH CITY, VIET NAM

Nguyen Hoang My Lan^{1,2,*}, Vo Le Phu², Le Van Trung²

¹*Faculty of Urban Studies, Ho Chi Minh City University of Social Sciences and Humanities, VNU-HCM, 10 – 12 Dinh Tien Hoang Street, District 1, Ho Chi Minh City*

²*Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology, VNU-HCM, 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City*

* Email: mylannh@hcmussh.edu.vn

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ABSTRACT

With the philosophy of stimulating ways that nature behaves under extreme weather conditions, Sustainable Urban Drainage System (SUDS) has been internationally recognized as one of the most sustainable approaches to minimizing the impacts of flooding on urban development coupled with the achievement of multiple benefits on environmental and social aspects. In this paper, the social aspect of SUDS is examined through the community's acceptance of a wide range of SUDS techniques, including Green Roof (GR), Rainwater Harvesting (RWH), Pervious Pavement (PP), Green Open Space (GOP), and Pervious Parking Lot (PPL). Data were collected through a social survey of community responses to above SUDS applications in Nhieu Loc – Thi Nghe sub-basin from November 2016 to March 2017, then SPSS software was used to analyze data and test statistical hypothesis. The results show that the most preferred SUDS technique is PP, followed by PPL, GOP, RWH and GR respectively. Through statistical hypothesis test, the relationship exists between (1) the community's acceptability to proposed SUDS techniques and district as well as gender; (2) the community's acceptance for and their knowledge of SUDS applications; and (3) the priority of SUDS's benefits between the districts and acceptability as well as understanding of SUDS applications.

Keywords: Sustainable Urban Drainage System, community's acceptability, Nhieu Loc – Thi Nghe sub-basin, urban flood.

1. INTRODUCTION

While conventional drainage system works to drain and convey the stormwater as quickly as possible, the Sustainable Urban Drainage System (SUDS) is designed to stimulate ways, as similarly as possible, that Nature behaves under extreme weather conditions. Therefore, the benefits of SUDS include reducing the impact of development on the quantity and quality of

run-off and creating amenity as well as ecology improvements which is classified as social benefits [1]. An actual SUDS scheme or treatment train could help reduce the flow rate and volumes and water pollution, as well, and should have a series of drainage techniques ranging from prevention, source control, site control and regional management, respectively. Through the SUDS scheme, wherever possible, stormwater and run-off should be managed and infiltrated into the ground by landscape features, such as rain garden, swale, pond, rather than being conveyed to and stored in large conventional pipelines and treatment stations. Building an ideal treatment train with a full range of SUDS components is more practical for new development areas than existing dense urban areas due to the limitation of available spaces for complete installation [2]. Hence, retrofitting existing stormwater management measures and turn them into green infrastructures are the most sustainable and perspective approach for flooding control in rapidly urbanized areas, like Ho Chi Minh City where 660.2 km² of cropland was converted to urban area from 1900 to 2012 [3]. In SUDS treatment train or management train, techniques in prevention and source control should be preferred to others in site and regional control, which can be feasible and cost-effective in developed areas. The residents in Ardler Village in Dundee, Scotland, UK were willing to pay more for their properties near the green spaces provided by SUDS features [4]. Hence, the more the residents know about SUDS functions or benefits, the more they pay for retrofitting SUDS in their places of living. In term of social benefits, the most common criterium used to assess SUDS sustainability is the community acceptability.

Therefore, the objective of this paper is to examine the acceptability of residents to some SUDS methods to be retrofitted in Nhieu Loc – Thi Nghe sub-basin, one of the central drainage catchments in Ho Chi Minh City. Given with a highly dense built-up area of Nhieu Loc – Thi Nghe sub-basin, the proposed SUDS techniques are Rainwater Harvesting (RWH), Green Roofs (GR), Pervious Pavement (PP), Green Open Space (GOP), and Pervious Parking Lot (PPL). Then, this paper also aims to answer the following questions: (1) What is the community preference for proposed SUDS techniques?, (2) What are the factors that affect the community's acceptance? Demographic or knowledge of SUDS techniques and benefits?, and (3) What is the priority of SUDS benefits to be considered when choosing certain flood control measure?

2. METHODOLOGY

2.1. Study area

Ho Chi Minh City (HCMC) locates in the downstream section of the Dong Nai and Sai Gon rivers in South of Vietnam, and more than 60 % of the city land is lower than 2 meters above the sea level [5], resulting in vulnerability to water-logging and floods. Moreover, tidal surges, upstream discharges, excessive rainfall and combinations of these are also the major reasons causing flooding in HCMC. And conversely, the rapid population growth, the obsolete conventional drainage system, and the unplanned urban development are the subjective factors contributing to the currently serious flooding situation in HCMC.

Since the release of the City's Master Plan of Drainage System to 2020 in 2001 up-to-date, the Nhieu Loc – Thi Nghe (NL-TN) sub-basin with the area of 33.2 km² is one of the drainage catchments in the old central part of Ho Chi Minh City. This sub-basin comprises entire Phu Nhuan district and part of districts 1, 3, 10, Tan Binh, Go Vap, and Binh Thanh (Figure 1), all of which are the inner urbanized areas resulting in the largest impervious surface areas in comparison with other catchments. Land elevation in NL-TN sub-basin ranges from 0.5 m to 10.6 m and ascends from the NL-TN canal toward the Northern and the Southern areas. The

Eastern areas (including Binh Thanh district) has the lowest elevation which creates the most frequently and seriously flooded routes, including the deepest and the most spreading areas within the city [6].

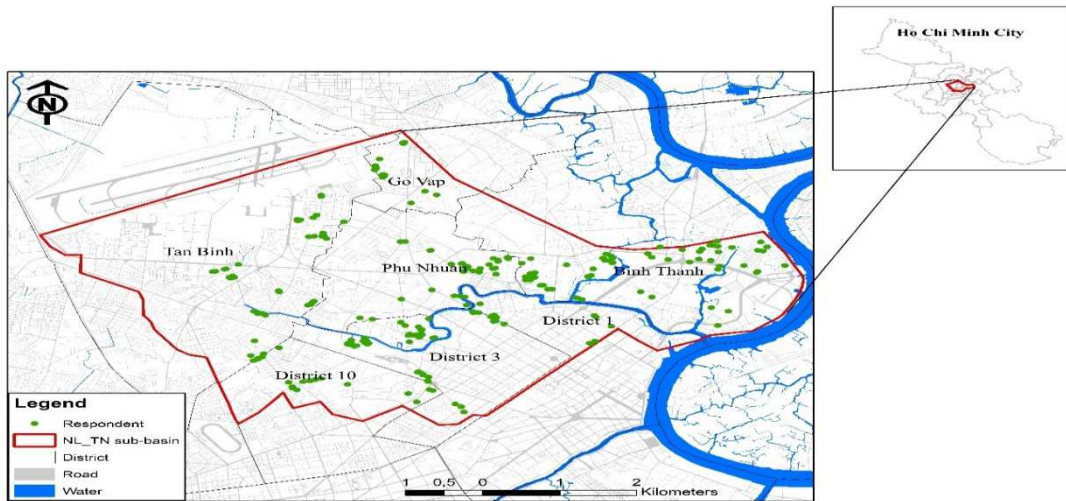


Figure 1. The study area and locations of survey respondent.

2.2. Data collection and processing

A face-to-face interview was conducted by questionnaire survey from November 2016 to March 2017. The total number of respondents was 265 and distributed randomly in the whole of NL-TN sub-basin, except those under 18 years old. More than 60 % of the respondents was selected in the areas around the NL-TN canal (districts 1, 3 and Phu Nhuan) and the Eastern of the basin (Binh Thanh district) where flooding has occurred more frequently (Figure 1). The number of interviewees in the Western was fewer due to limited accessibility, where there are the Tan Son Nhat Airport and many high security locations. Before the actual survey, a pilot study was conducted in September 2016 to test, remove the biased questions, and offer feedback on the clarity and competence of the questionnaire. The finalized questionnaire included 17 questions divided into four parts: (1) Flooding situation and solution applied in the communities, (2) The acceptability to SUDS and every SUDS technique, (3) The priority to benefits of flooding control solutions, and (4) Demographic information. The 5-Likert scale was used to quantify the answer to most questions in the first three parts. In terms of acceptability, 1 in 5-Likert scale represents for *Strongly disagree* and 5 represents for *Strongly agree*. In addition, the residents in NL-TN sub-basin were asked to possibly give their reasons to agree or disagree with every SUDS techniques. While regarding SUDS benefits, 1 to 5 denotes *Lowest* to *Highest* in ranking the priority. In this survey, the benefits consist of *Flood reduction*, *Environmental enhancement*, and *Amenity*.

Data from the questionnaire were then analyzed by the Statistical Package for the Social Sciences (SPSS) software (Version 23). Data analysis processing provided two types of information: descriptive statistics and bivariate analysis. Descriptive statistics describe the demographics of the respondents in NL-TN sub-basin as well as their consideration of SUDS techniques and benefits. To examine the difference between groups of SUDS techniques or SUDS benefits, *Friedman test* and *Wilcoxon signed-rank test* are appropriate methods for ordinal variables, such as acceptability and priority. The correlation tests, in this study, were *Chi-square*

test for independence for almost all observed variables and *Kendall correlation test* for ordinal variables which had more than two categories. The null hypothesis was that the two or more than two sets of measures were similar, used in Chi-square test and that there was no correlation between two variables, used in Kendall correlation test. The significant value (*p-value*) of 0.05 or 95 percent confident was used to retain or reject the null hypothesis. Phi and Spearman rank (Spearman's rho) correlation coefficient were then used to measure the strength of the relationship between two variables after claiming that the relationship existed significantly. Both Phi and Spearman's rho vary from -1 to 1 where positive value indicates a direct relationship and negative denotes an inverse correlation. The higher coefficient is, the stronger relationship exists between tested variables.

3. RESULTS AND DISCUSSIONS

Most of the respondents are female (54.7 %) and above 40 years old (75.1 %). Women in the survey spend most of their time to take care of their houses. Thus, they showed their anxieties for the techniques that would be installed at their premises and have difficulties in either operation or maintenance. The majority of the respondents stated that their monthly household income belonged to Upper-middle (26.1 %, from 7.5 million VND to 15 million VND) and High-income groups (45.6 %, more than 15 million VND). For further correlation test, the age of respondents was classified into four groups: younger than 25, 26 – 45, 46 – 55, and older than 55, occupying 4.2 %, 20.8 %, 35.1 %, and 40 %, respectively. In the extent of NL-TN sub-basin, Binh Thanh district had the most concentration of respondents (approximately 30 %), followed by district 3, Tan Binh, Phu Nhuan, Go Vap, district 10, and district 1, respectively (Figure 1).

Based on the land-use and topographical characteristics of NL-TN sub-basin, five SUDS techniques were proposed to retrofit the existing drainage system, namely Rainwater Harvesting (RWH), Green Roof (GR), Pervious Pavement (PP), Green Open Space (GOP), and Pervious Parking Lot (PPL). Regarding stage of SUDS treatment train, these methods consisted of two from Prevention (GR and RWH), one from Source control (PP), and two from Site control (GOP and PPL). Besides, concerning the ownership of land, there were two methods installed in private spaces (RWH and GR) and the rest applied in public areas (PP, GOP, and PPL). A great majority of the respondents (96.2 %) had no idea about the concept of sustainable urban drainage system. But, after being explained, most of them were impressed by proposed techniques' performance in a sustainable way, though they used to apply these techniques, for example, rainwater harvesting and green roofs. Remarkably, the residents would be willing to get involved in SUDS retrofit if they had financial assistance from the City government and high agreement from the local community.

Rainwater Harvesting can be designed to maximize rainwater capture and reduce run-off during extreme weather events. The harvesting of rainwater refers to the collection of water from surfaces on which rain falls and subsequently storing this water for later use [7]. Besides, domestic household rainwater harvesting has the potential to groundwater recharge, resulting reduction in the rate of land subsidence. However, there is still much concern about the quality of rooftop, stored rainwater, including chemical and microbiological factors [7], and available spaces for storage installation. "*Not enough space*" was the most important reasons for the respondents to be unwilling to accept RWH. Because NL-TN sub-basin has dense built-up areas and the perfect water supply network, the residents didn't want to collect or store rainwater, which was the second reason for them to disagree (Figure 2). *Green Roofs* are the systems which

cover a building’s roof with vegetation and designed to increase localized infiltration, attenuation and/or detention of stormwater [8]. GR is one of the SUDS components which can meet all the three goals of sustainability: water quality, water quantity, and amenity [9]. Nevertheless, “No cost-effectiveness” was confirmed by 50 interviewees (nearly 40 % of those who did not accept GR in NL-TN sub-basin) to be the reason to disagree because GR’s benefits have been underestimated by the communities.

Generally, pervious surfaces, such as *Pervious Pavement*, *Green Open Space* and *Pervious Parking Lot*, allow rainwater to infiltrate through the surface into an underlying storage layer, where water is stored before infiltration to the ground, reuse or release into surface water [1]. Permeable pavements could be the most promising performance of the Sustainable Urban Drainage System to provide storage capacity for extreme rainfall as well as to control the quality of water environment so as to meet the good status required by environmental agencies [10]. However, the operation and maintenance of pervious surfaces may be costly and need new skills [11] are the reasons for those who totally disagree to install pervious surfaces (63 of 124 comments) (Figure 2).

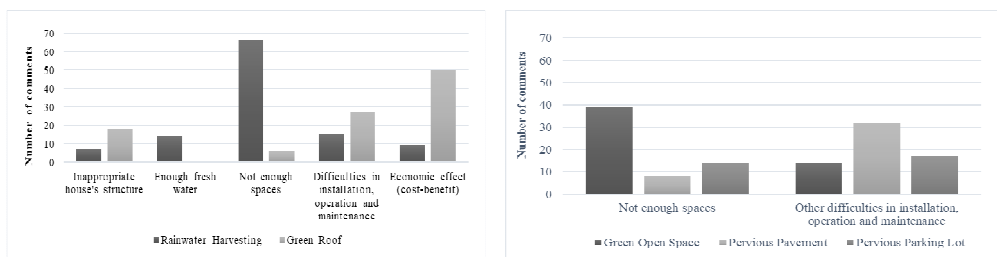


Figure 2. Reasons to strongly disagree to accept RWH and RG (left), and GOP, PP, and PPL (right).

Table 1. Chi-square test for independence between acceptability to SUDS techniques and gender, district, SUDS knowledge, and relevant techniques

	Gender ^a	Age ^b	Income ^b	District ^a	SUDS knowledge ^a	Understanding of corresponding application ^a
RWH acceptability	0.214*	-0.157*	-0.035	0.473*	0.075	0.506*
GR acceptability	0.146	-0.012	0.050	0.436*	0.067	0.520*
GOP acceptability	0.048	0.093	0.017	0.325	0.073	0.564*
PP acceptability	0.076	-0.113**	-0.053	0.372*	0.075	0.558*
PPL acceptability	0.172**	-0.126*	-0.096	0.407*	0.203*	0.430*

^a Phi correlation efficient, ^b Spearman’s rho correlation efficient, * $p = 0.05$; ** $p = 0.1$

In the survey, after being explained about every SUDS techniques’ properties, the respondents are asked to state their agreement to accept these techniques on a scale of 1 to 5, with 1 – “Strongly disagree” and 5 – “Strongly agree”. The percent of interviewees totally not accepting to equip their houses with RWH and GR is from nearly 1.4 to 2 times more than not to retrofit GOP, PP, and PPL. In NL-TN sub-basin, the proposed SUDS techniques are allowed more in Binh Thanh and Go Vap, where inundation occurred more frequently and severely than in the others due to the limitation of available spaces. Based on the results of Chi-square test (Table 1), these differences of acceptability by places are statistically significant, and these

associations are from moderate to strong relationships ($0.3 < \text{Phi coefficient} < 0.4$). Besides, another factor to make strong positive relationships with SUDS acceptability is the understanding of technique itself, thus the City government should improve the community perception of SUDS as well as its benefits in flooding management before planning to retrofit current drainage system.

Table 2. Statistics of Wilcoxon signed-rank test.

	Z*	Sig. (2-tailed)
<i>GOP acceptability – RWH acceptability</i>	-5.036	0.000
<i>PP acceptability – RWH acceptability</i>	-8.799	0.000
<i>PPL acceptability – RWH acceptability</i>	-5.348	0.000
<i>GOP acceptability – GR acceptability</i>	-5.711	0.000
<i>PP acceptability – GR acceptability</i>	-9.059	0.000
<i>PPL acceptability – GR acceptability</i>	-5.526	0.000

* based on the positive rank

Table 3. Chi-square test for independence between SUDS benefits and gender, district, and SUDS knowledge.

			Gender ^a	Age ^b	Income ^b	District ^a	SUDS knowledge ^a
	Mean	Median					
<i>Flood reduction</i>	3.44	4	0.109	0.049	-0.206*	0.504*	0.163*
<i>Environmental enhancement</i>	3.49	4	0.120	0.026	0.101	0.336	0.083
<i>Amenity</i>	3.06	3	0.075	0.066	0.098	0.389*	0.174*

^a Phi correlation efficient, ^b Spearman's rho correlation efficient, * $p = 0.05$

A Friedman test was then carried out to see if there were differences in acceptability to proposed SUDS techniques in NL-TN sub-basin. The results show that there was a statistically significant difference in acceptability to SUDS techniques in NL-TN sub-basin depending on which type of techniques would be installed ($\text{Sig.} = 0.000 < 0.05$). To examine where the difference actually occurs, a Wilcoxon signed-rank test was then run on each of combinations of SUDS techniques in turn. Because of making multiple comparisons, a Bonferroni adjustment needed to be calculated to declare the final significance level, by dividing initial p value by the number of compared combinations. In this case, ten combinations of five proposed SUDS techniques was created and then the final p value equals to 0.005. However, to focus on the difference between two source control methods and other permeable surfaces, six pairs of SUDS techniques would be tested as described in Table 2. As the results, statistically significant differences existed between source control (RWH and GR) and site control methods (GOP, PP, and PPL) because *Sig. (2-tailed)* was smaller than final p value. Moreover, all Z scores in Wilcoxon test were negative and calculated based on the positive rank in which the first element in each pair had a higher value than the latter. For example, GOP acceptability was significantly higher than RWH acceptability with the Z score of -5.036. Indeed, median acceptability rating was 1, 1, 2, 3, and 2 for RWH, GR, GOP, PP, and PPL respectively. Thus, it could be concluded

that the most preferred SUDS technique in NL-TN sub-basin is PP followed by GOP and PPL, while RWH and GR are the least accepted methods for flood control.

In addition, for further selection overall SUDS techniques, the respondents were asked to identify their priority for SUDS benefits, including Flood reduction, Environmental enhancement and Amenity, which are the general benefits of SUDS. Table 3 shows that there was no statistically significant relationship between either of demographic information, places of living or the understanding of SUDS and the environmental function of SUDS in NL-TN sub-basin. As community's acceptability, the priority of SUDS benefits also depended significantly on districts, in which Binh Thanh had the highest rank of all benefits. Inversely, the respondents in district 3 and 10 set the lowest priority for all three SUDS benefits because they have rarely faced with serious inundation and lived in slightly beautiful landscapes, as well. The residents in NL-TN sub-basin generally set an equal median rank for the ability to reduce flooding and to improve environmental quality meanwhile they rank amenity one level lower.

4. CONCLUSIONS

This case study was conducted to identify the opportunities for SUDS applications in NL-TN sub-basin based on the community perspectives. While gender, age, district and the understanding of SUDS techniques had statistically significant impact on the acceptability to proposed SUDS techniques, SUDS benefits depended on households' income, district and SUDS knowledge. Remarkably, there were moderate to strong relationships between the districts and all three SUDS-related variables, including the knowledge, the acceptability, and the priority. Moreover, the residents in NL-TN sub-basin set an equal rank for the ability to reduce flooding and to improve environmental quality meanwhile they rank amenity one level lower, possibly because flooding occurred more frequently and severely in the last ten years.

Due to land-use characteristics, the appropriate SUDS techniques to be applied in NL-TN sub-basin consists of RWH, GR, GOP, PP, and PPL. The most accepted technique by the community was PP, followed by PPL, GOP, GR, and RWH, respectively. In other words, the applications to be installed in resident's premises were less preferred than those to be retrofitted in public areas because they had to face with many difficulties in installation, operation, and maintenance while they did not realize any monetary benefits from using these techniques.

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